CENTRAL-STATION APPLICATIONS
System and Subsystem Research Activities*

SANDIA NATIONAL LABORATORIES

G.J. Jones

Photovoltaic central power stations were first analyzed in three parallel studies by General Electric Co., Spectrolab, Inc., and Westinghouse Electric Corp., published in 1977. A number of questions raised in these efforts have been the subject of more focused research over the last few years. This presentation reviews the work done in this area by Sandia National Laboratories as part of their system and balance-of-system research activities. The work has been broken into three topical areas starting with subsystems, proceeding to detailed design definition, and culminating in the analysis of the system's value to, and impact on, the utility.

Several flat-panel array field design studies, for both large intermediate and central-station applications, predict that $\$50/m^2$ area-related costs are achievable, by a number of concepts. This cost is based on vendor quotes and construction contractor bids. In the future, use of automation and robotics in structure placement and panel installation may be able to lower this cost by 20%. In the area of power conditioning, central-station-sized equipment has been developed for other technologies, but not yet for photovoltaics. Conceptual designs for such a unit will be sought in the near future.

Bechtel recently completed a study of electrical design tradeoffs for multimegawatt systems. They analyzed such factors as the subfield size versus voltage, energy loss, and power-conditioning and wiring cost. These results indicate that 5 MW subfield operating at 2000 Vdc bipolar ($\pm$ 1000 Vdc) is near optimum and does not adversely impact collector design. All of the results of this study, as well as the utility requirements identified in the test facility design studies, have been incorporated into the reference designs being developed by Martin Marietta. These designs are site-specific and utilize existing prototype hardware. There is active utility (APL) participation in this work and an experienced construction engineering firm (Stearns-Rogers) as subcontractor.

The analysis of central-station plant value and impact on the utility is a relatively new activity. The value of PV central station plants as a function of region can be determined from the energy scenario effects study, recently completed by General Electric. This work focused on distributed PV applications but the value analysis is equally applicable to central stations. Regions with high oil and gas use were found to offer high value, as would be expected. The analysis of the impact of PV systems on the utility's spinning reserve requirements will be studied by Arizona State University. This work will be directed by Paul Anderson and will involve utility consultants on generation planning, dispatch, and distribution.

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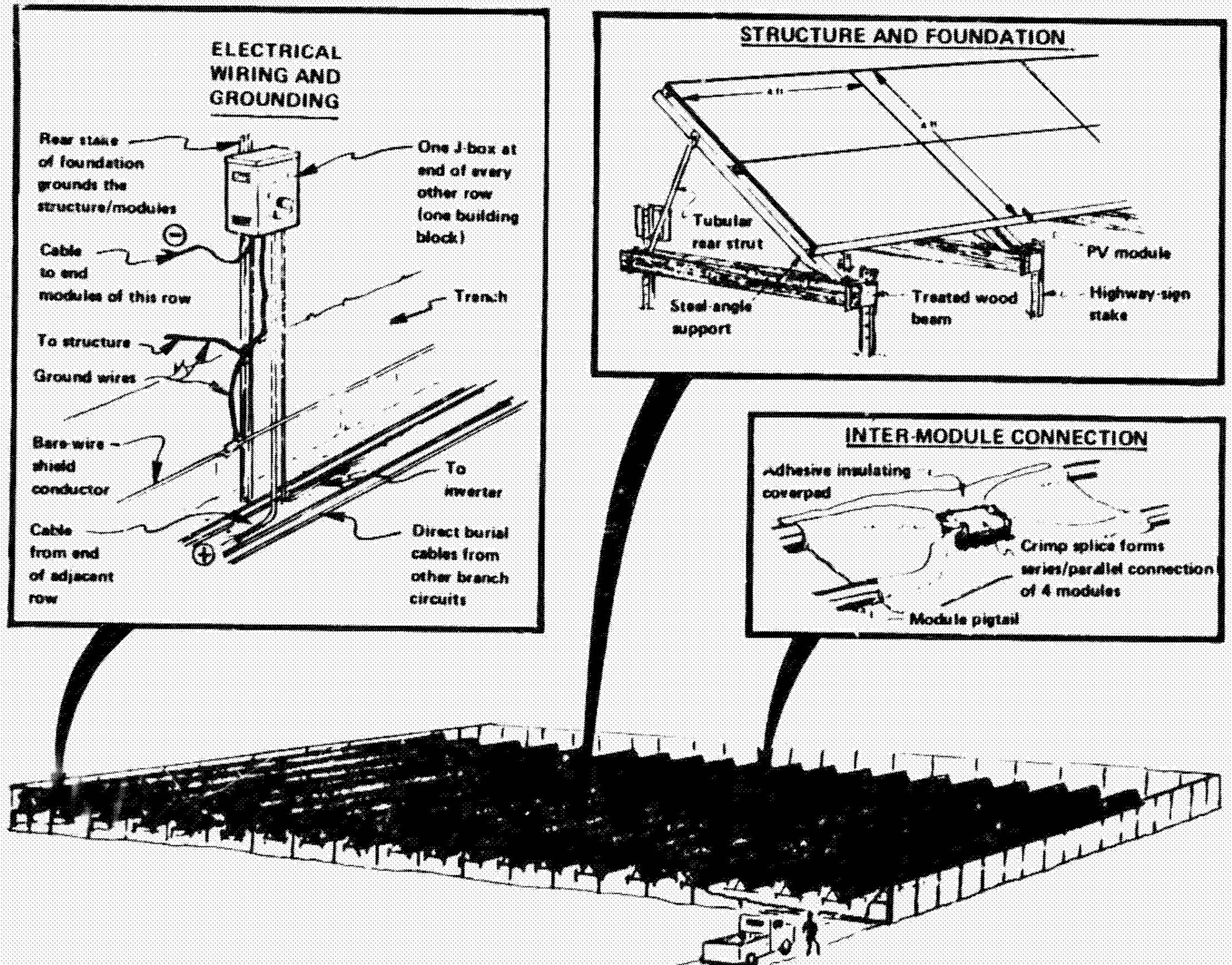
AREAS OF RESEARCH:

- Array Field Engineering and Power Conditioning Development
- Design Tradeoff Analysis and Detailed Design Preparation
- Utility Value and Operational Impacts Determination

Array Field Engineering

- Modular Array Field Designs
  (20-500 kW Subfield)
  - Battelle-Columbus (SAND81-7183)
  - Hughes (SAND81-7193)
- Integrated Array/Structure Design
  - Bechtel (SAND81-7191)
- Automated Installation Techniques
  - Burt Hill Kosar Rittleman (SAND81-7192)



PHOTOVOLTAIC ARRAY FIELD USING BATTELLE'S LOW-COST BUILDING BLOCK DESIGN

100-kW Array field consists of 10 building blocks, 2 rows each. Size to fence is ~185 x 195 ft.

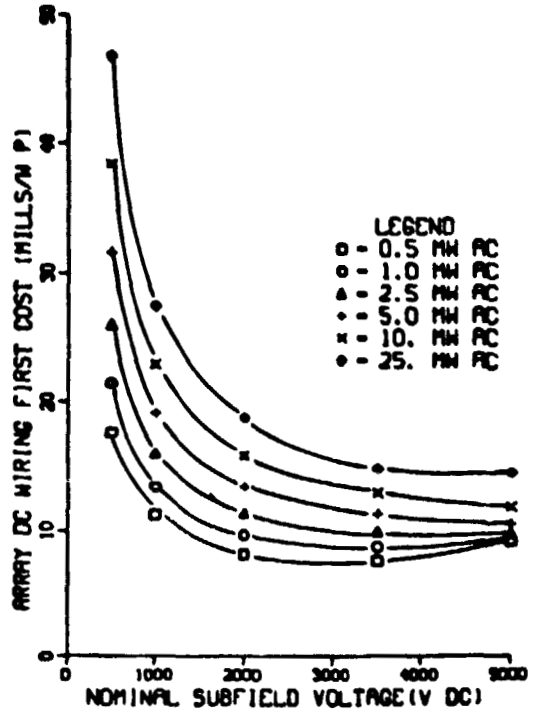
Array Field Design Summary

- Construction Contractor Costing of Array Field Designs Predict Area-Related BOS Costs of $\$50/m^2$. (Site Prep., Structure, Installation, Wiring, Etc.)

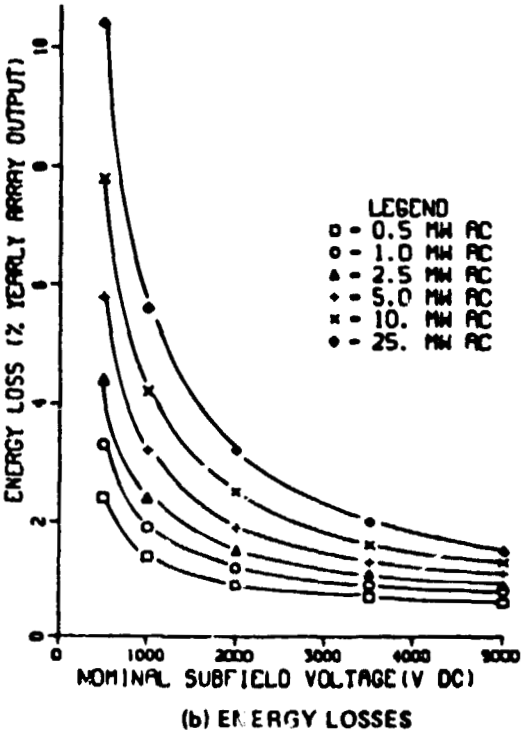
- An Appropriate Mix of Automated and Conventional Installation Methods May Reduce Costs by About $\$11/m^2$.

Design Tradeoffs and Detailed Preparation

- Central Power Station Test Facility Design
  - Bechtel (SAND79-7012)
  - General Electric (SAND79-7022)
- Subsystem Optimization and Design Tradeoff Study
  - Bechtel (SAND81-7013)
- Central Station Reference Design
  - Martin Marietta (In Progress)



(a) FIRST COSTS



(b) ENERGY LOSSES

Vertical Axis Array Dc Wiring First Costs and I^2R Energy Losses - 25 Meter Diameter, 15 Percent Efficiency

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Central-Station Reference Design (Martin-Marietta)

- Site Specific Design Using Actual Soil and Terrain Characteristics
  - Saguaro Power Station, APS
- Two Complete 100 MW Field Designs
  - Flat Plate: Dendritic Web Modules and Bechtel Integrated Structure Design
  - Concentrator: Martin-Marietta Mod 2 Point Focus Fresnel
- Field Characteristics Based on Subsystem Optimization Study
  - 5 MW (ac) Subfield
  - 2000 V Bipolar dc Wiring
  - 34.5 kV Infield ac Distribution

Design Information Summary

- Several Techniques Have Been Found to Reduce In-Field dc Wiring
- Almost All Economies of Scale and Energy Loss Minimization Can Be Achieved by 5 MW, ± 1000 Vdc Subfield
- Design Tradeoffs Must Consider Life Cycle Value of Energy Loss in Conjunction With First Cost to Determine Optimum.

Utility Value/Impact Determination

- The Effect of Future Energy Scenarios on Photovoltaic Energy Value
  - General Electric (SAND81-7012)
- The Impact of Stochastic PV Energy Supply on Utility Operations
  - Arizona State University (In Progress)

Utility Value Determination

- Regions with High Oil and Gas Usage in Intermediate and Base Load Generation are Favored.
- Only Future Scenarios Affecting Oil/Gas Use and Value Effect PV Energy Value in These Regions.
- Distributed and Centralized PV Plants Have the Same Energy Value to the Grid (Assuming Negligible T&D Impact).